

The future of Space Astrophysics
is in your hands

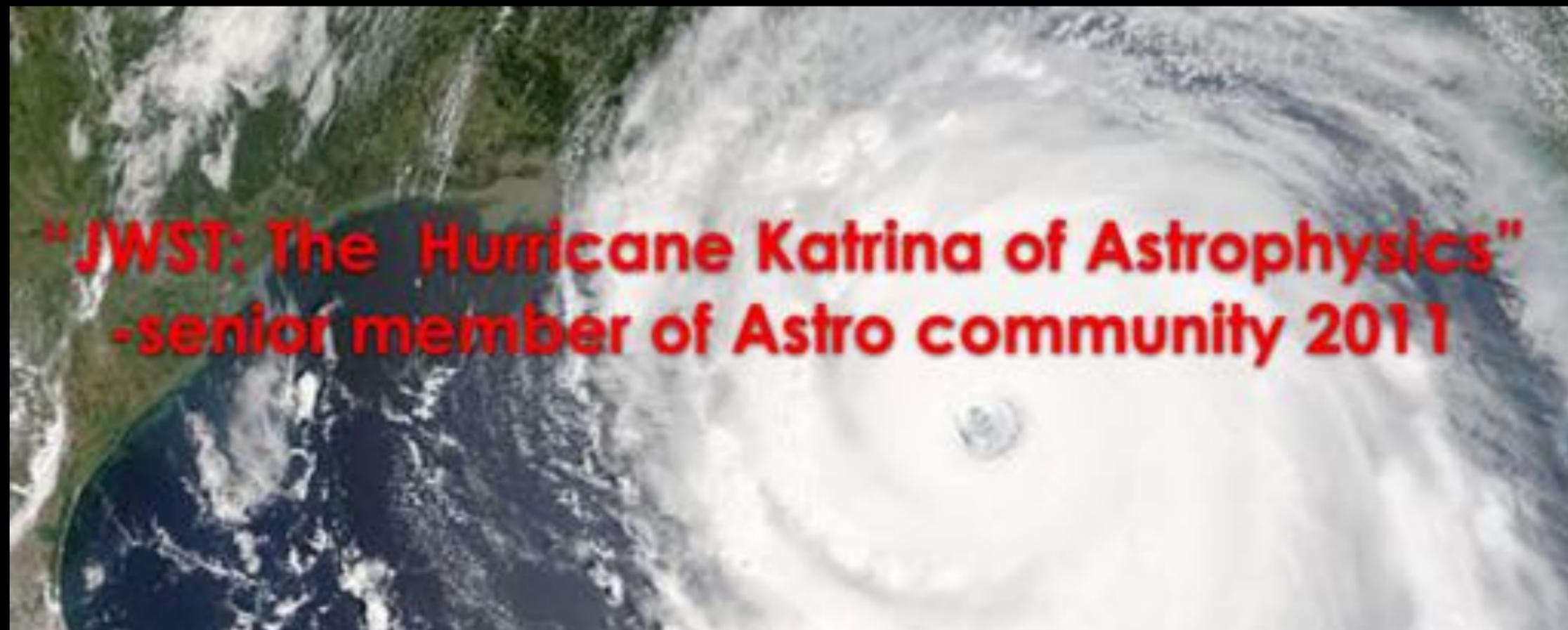
Matt Mountain
11th October, 2016

views expressed are solely
mine, and not representative
of those whose charts I stole



Myths our community love...

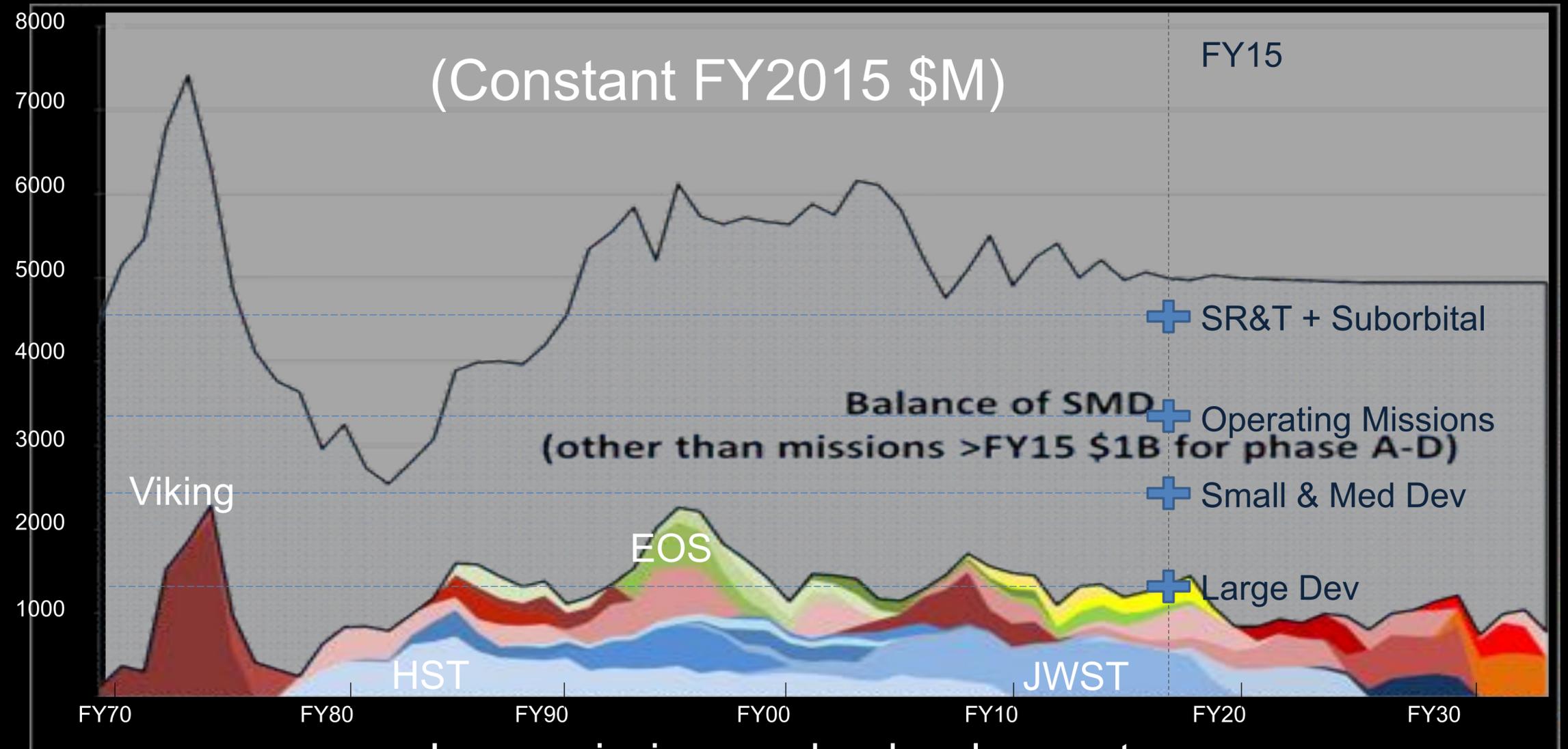
- ➔ most of the budget goes to flagships, or operating flagships, or flagships “eat the lunch” of other missions when they overrun.
- ➔ JWST did “eat our lunch...”



Relying on data, not mythology

SMD Balances Large, Medium, and Small Missions

- Large missions (> \$1B LCC) account for ~30% of SMD's budget

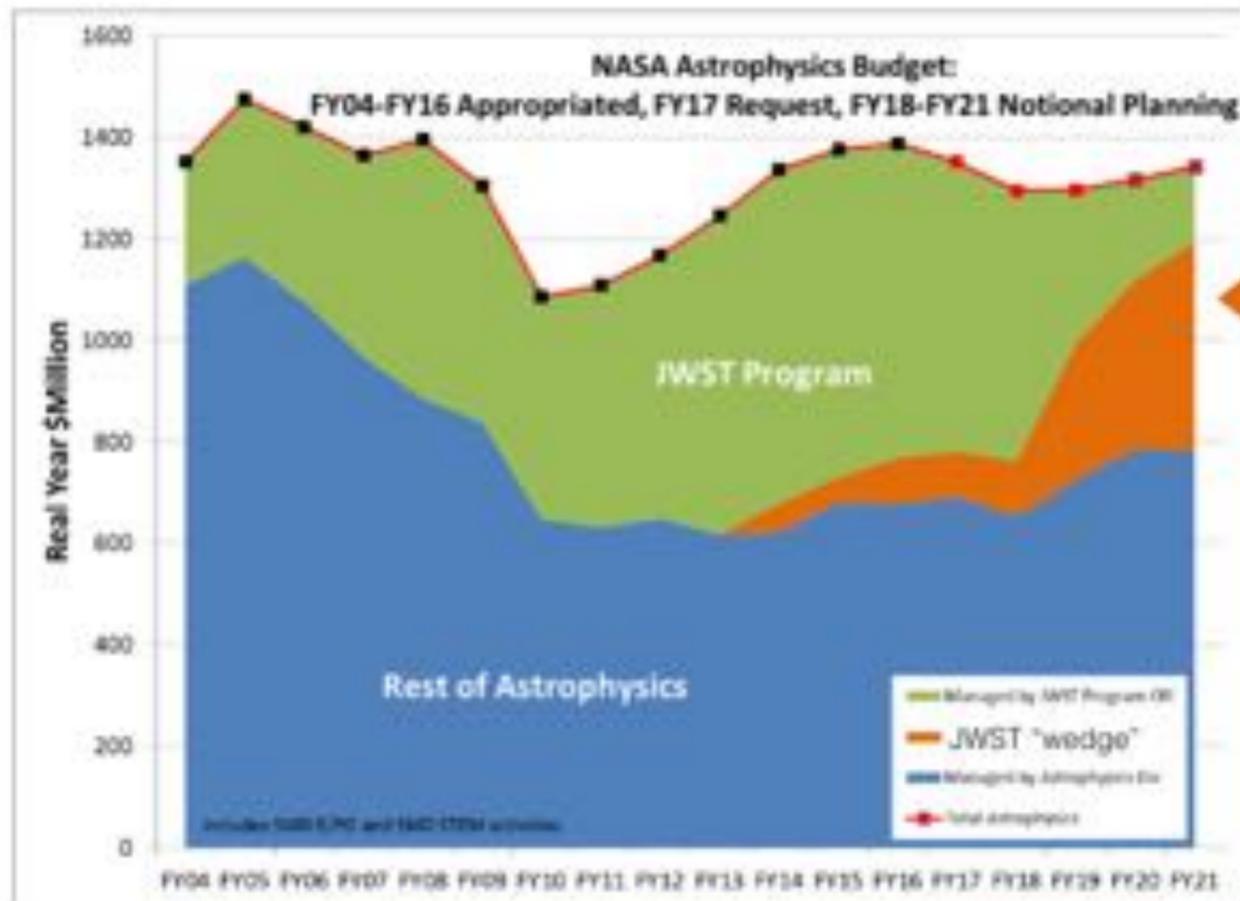


T. Zurbuchen, 10/5/16
J. Gunzfeld, 10/6/16

Large missions under development
as a portion of total SMD budget
FY1969-2034

Relying on data, not mythology

In Space Astrophysics, the job is now to **hold on the JWST wedge**



← Can we hold on to this?

At NASA there is still a queue:

- Commercial Crew
- The Space Launch System
- Earth Science
- Planetary Science "Europa"
- Astrophysics

"without JWST, Astrophysics would have a budget of roughly \$600M/yr"

J. Gunsfeld, 10/6/16

"I agree, and looked what happened to the money for SOFIA."

Paul Hertz, 10/6/16

NAS Study Large Strategic NASA Science Missions:
Science Value and Role in a Balanced Portfolio

Myths our community love...

→ a LUVOIR will cost at least \$20B.....

How do we know this?

→ well, just scale JWST....."the Katrina of Astrophysics"

Relying on data, not mythology

NASA

Multivariable Parametric Cost Models for Space and Ground Telescopes

H. Philip Stahl
NASA MSFC, Huntsville, AL 35821;

Todd Henrichs
Missile Defense Agency

Normal Incidence Database (8.6.11)

Free Flying Telescopes	Attached Telescopes
Cloud SAT	HUT
Commercial #1	SOFLA
Commercial #2	UIT
Copernicus (OAO-3/PEP)	WUPPE
GALEX	
Herschel	
HST	Planetary Telescopes
IRAS	MRO/HIRISE
JWST	
Kepler	
OAO-B/GEP	
Planck	
Spitzer (SIRTF)	
WIRE	
WISE	

NASA

FINDING

OTA is not Largest Mission Cost Element

OTA ~12%

Spacecraft and Instruments ~ 50% (**Invest here to reduce \$**)

Program Management & Systems Engineering equals OTA (**SSS**)

I&T ~ 10% (maybe another 10 to 15% of Subsystems)

Example of Mission Specific is Sun Shade for JWST

Composite WBS for 7 of 14 free flying missions.

Space Database: 33 UVOIR, X-ray, Radio

- Optical Telescope Assembly (OTA) ~ **12% of mission cost**, so if LUVIOR's mirror cost 4x JWST, it would increase JWST's "price" by \$2B ~ \$3B....
- Spacecraft and Instruments apparently **always** account for ~ 50% of total cost
- **BUT** as Casani 2010 (ICRP) said..with optimum funding profile JWST minimum-cost-to-launch= \$6.5B
see: http://www.nasa.gov/pdf/499224main_JWST-ICRP_Report-FINAL.pdf
- **AND** estimated costs of cooling JWST to 40K ~ \$2B....(see L. Feinberg next STDT meeting)

Bottom-line: real mission costs for a warm LUVOIR are not "intuitively scaleable"..

(its like comparing the cost of a segmented architecture to a new 4m monolith technology requiring as yet to be developed star-shade technology...)

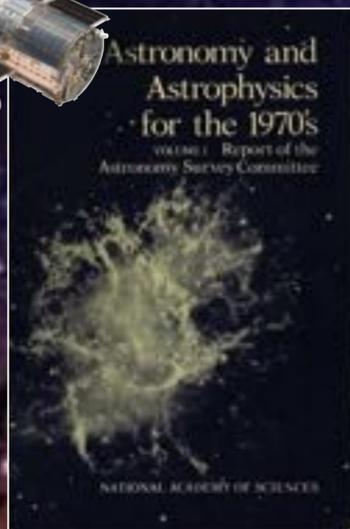
Myths our community love...

→ Decadal Surveys have only selected missions < \$3B

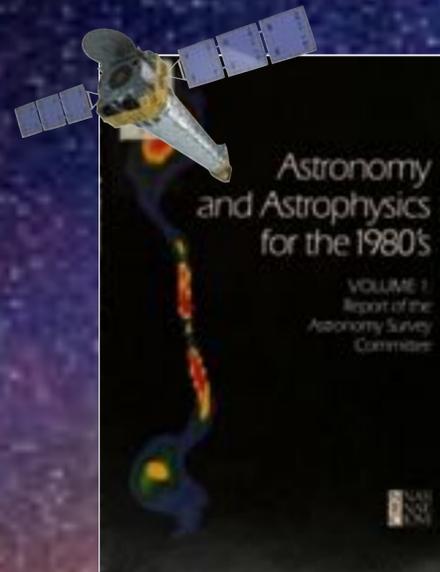
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J. Gunsfeld, 10/6/16

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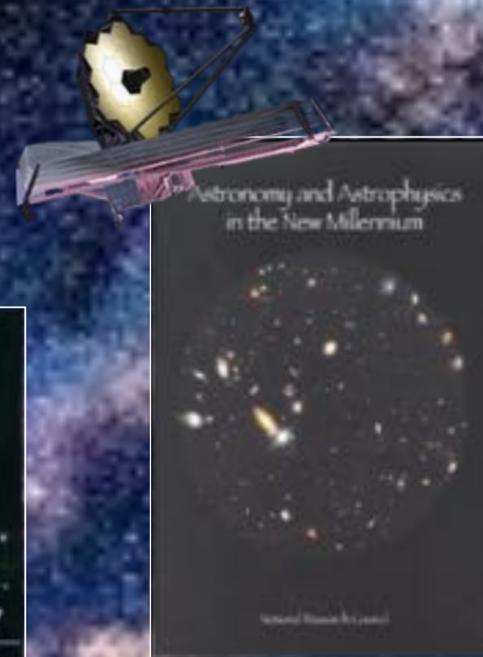
1972 - Hubble



1982 - Chandra



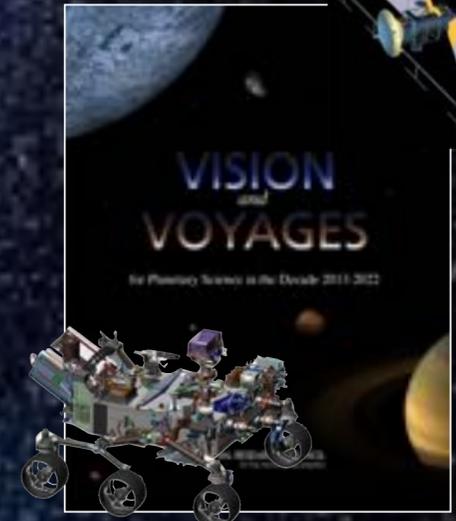
1991 - Spitzer



2001 - JWST



2010 - WFIRST

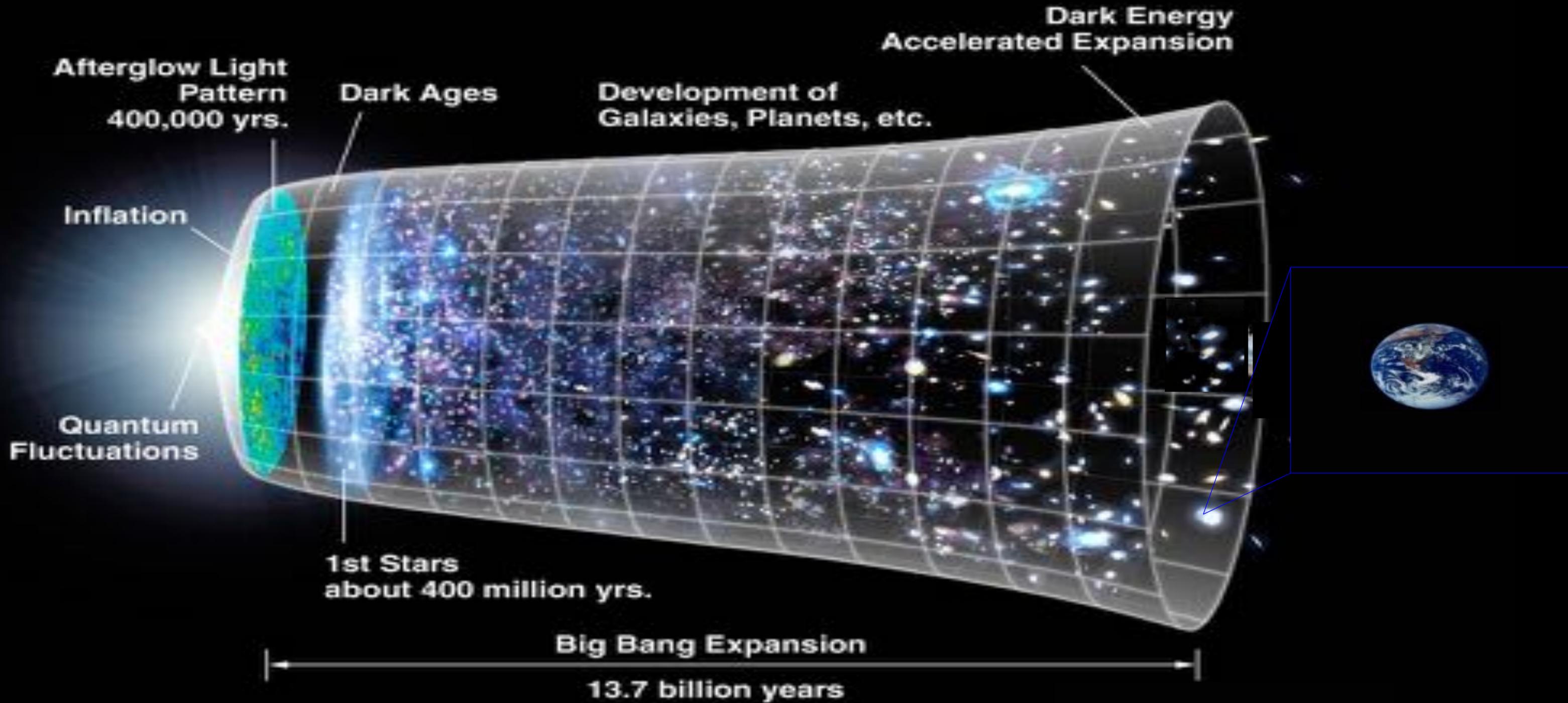


2011 - Mars and Europa

Flagships are the Foundation
of Decadal Surveys

Because they demand transformative science!
(and only 1 cost < \$3B (FY'16 \$))

The story so far, with a few details to fill in...



TELESCOPES AND THE MEANING OF LIFE



$$N_{L,T} = \cancel{N^*_{*,T}} \cdot \cancel{f_p} \cdot \cancel{n_e} \cdot f_l$$

Observable Drake Equation
(after Reid & Hawley, & Seager)

The New York Times

SCIENCE

One Star Over, a Planet That Might Be Another Earth

By KENNETH CHANG AUG. 24, 2016



An artist's impression of the planet Proxima b orbiting Proxima Centauri, the closest star to Earth's sun. M. Kornmesser/ESA/ESO/Reuters

theguardian

Proxima b: could we live on this newly found planet - or could something else?

The announcement that scientists think they may have found a planet orbiting the star nearest to our sun is potentially big news - even if it would take 70,000 years to get there



An artist's impression of Proxima b orbiting Proxima Centauri. Photograph: ESA/ESO/Reuters

Forbes



Astrophysicists Have Been Looking For Exoplanets Like Proxima B Since The 19th Century

Mashable

VIDEOS

SOCIAL MEDIA

Stop describing a planet as 'Earth-like' unless it really is

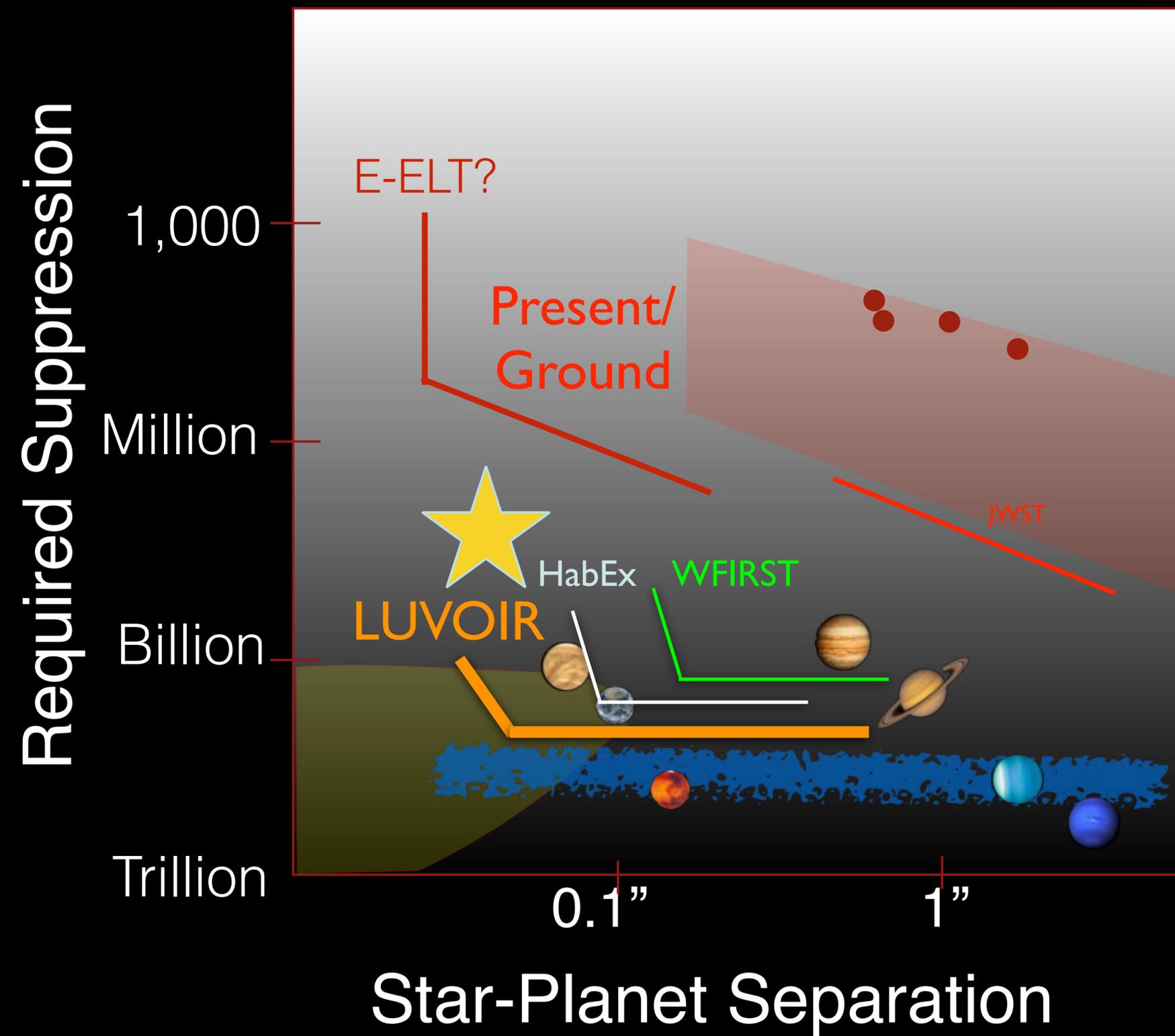
"The discovery ... provides an obvious target for a flyby mission," Avi Loeb, a physicist at Harvard University and a [Starshot mission advisory committee chair](#), wrote in an email to Business Insider.



Russian billionaire Yuri Milner holds up a Starshot "StarChip" prototype during an April 12, 2016, press conference in New York. Associated Press

Q: Can our suite of current & next generation telescopes directly image Proxima b?

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The tale of two different colliders...

The Tevatron



The Large Hadron Collider

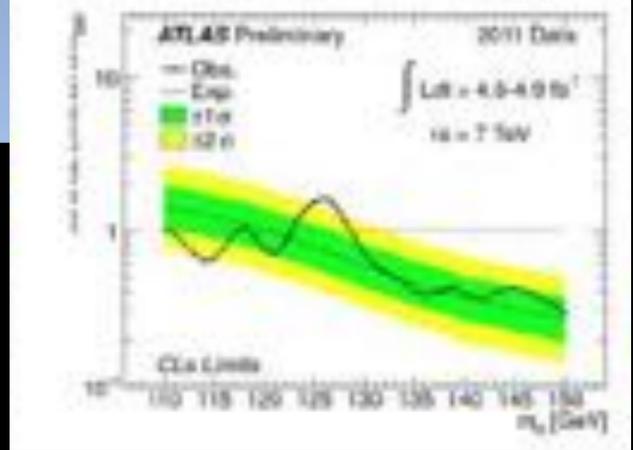
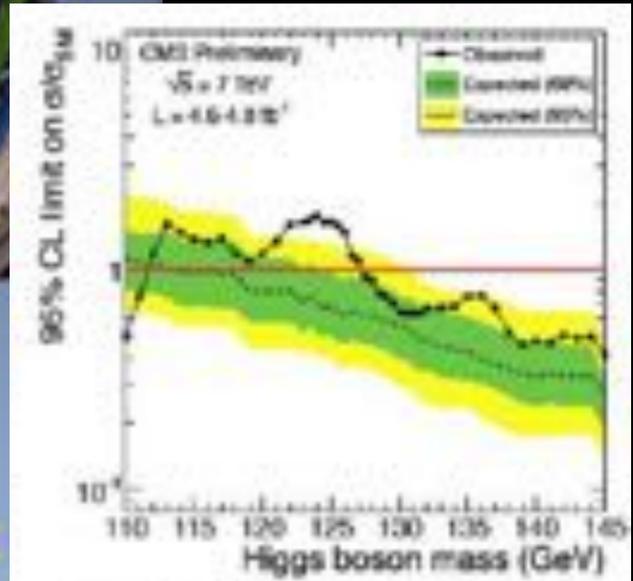
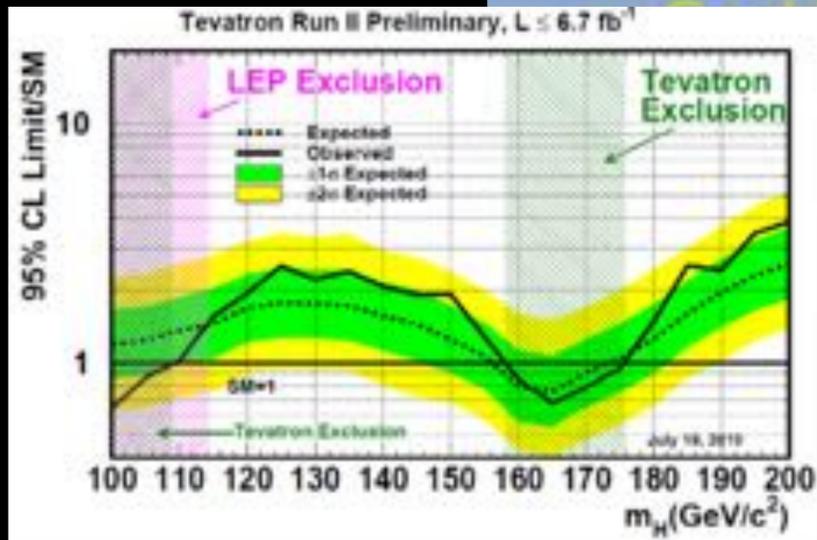


Done!

Maybe?

- Limited investment
- Incremental upgrades
- Goal for Run II was to detect Higgs Boson at 5 σ

- Big investment
- Large technological leap
- Goal was, arguably, to rule out the existence of the Higgs: a powerful null result



The Higgs

imagine the moment...





FYI: The AIP Bulletin of Science Policy News

A publication of the American Institute of Physics

Number 42: April 1, 2016

Congressman Culberson Hosts Hearing to Highlight NASA's Search for Extraterrestrial Life



"We live in an extraordinary time where the scientific community has revealed to the world that there are as many earth-like planets as there are stars in the sky. The amazing discoveries that Kepler [space observatory] has made...and the possibility for life on those other worlds and indeed within our own solar system has become very, very real."

Congressional
Appropriations
House
Senate

Commerce, Justice & Science Committee
(e.g. NASA & NSF)



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In his opening statement, subcommittee ranking member Mike Honda (D-CA) nearly matched Culberson in his fascination with the scientific questions behind the search for extraterrestrial life:

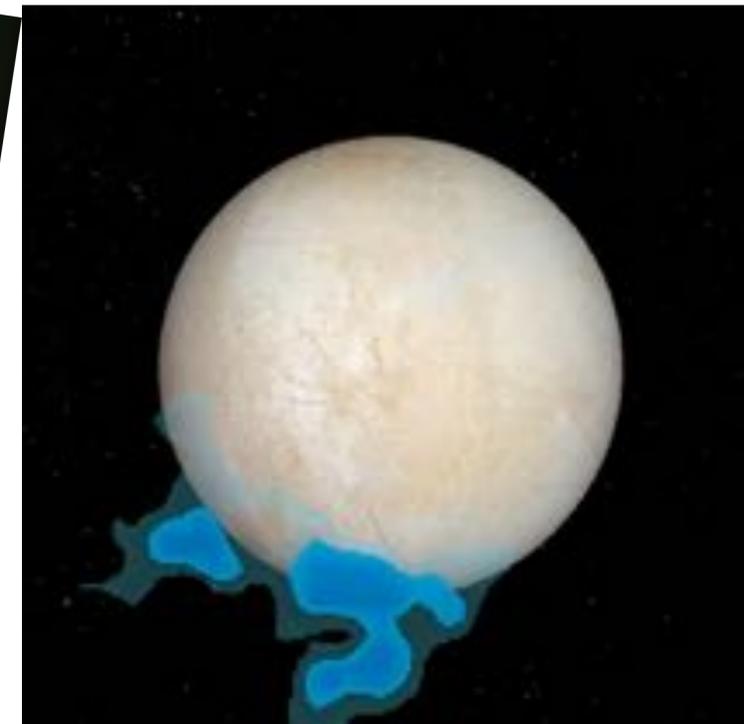
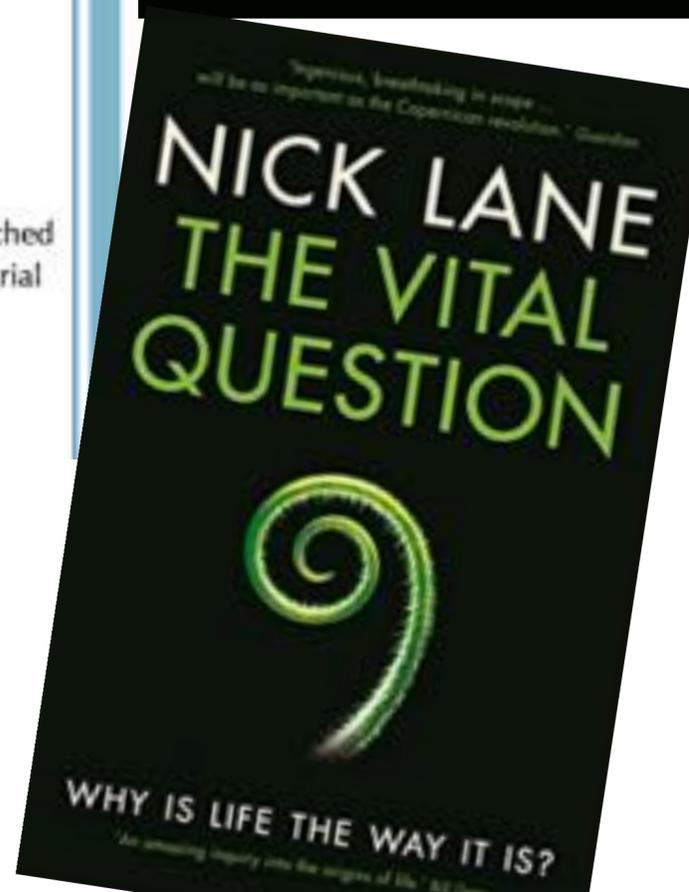
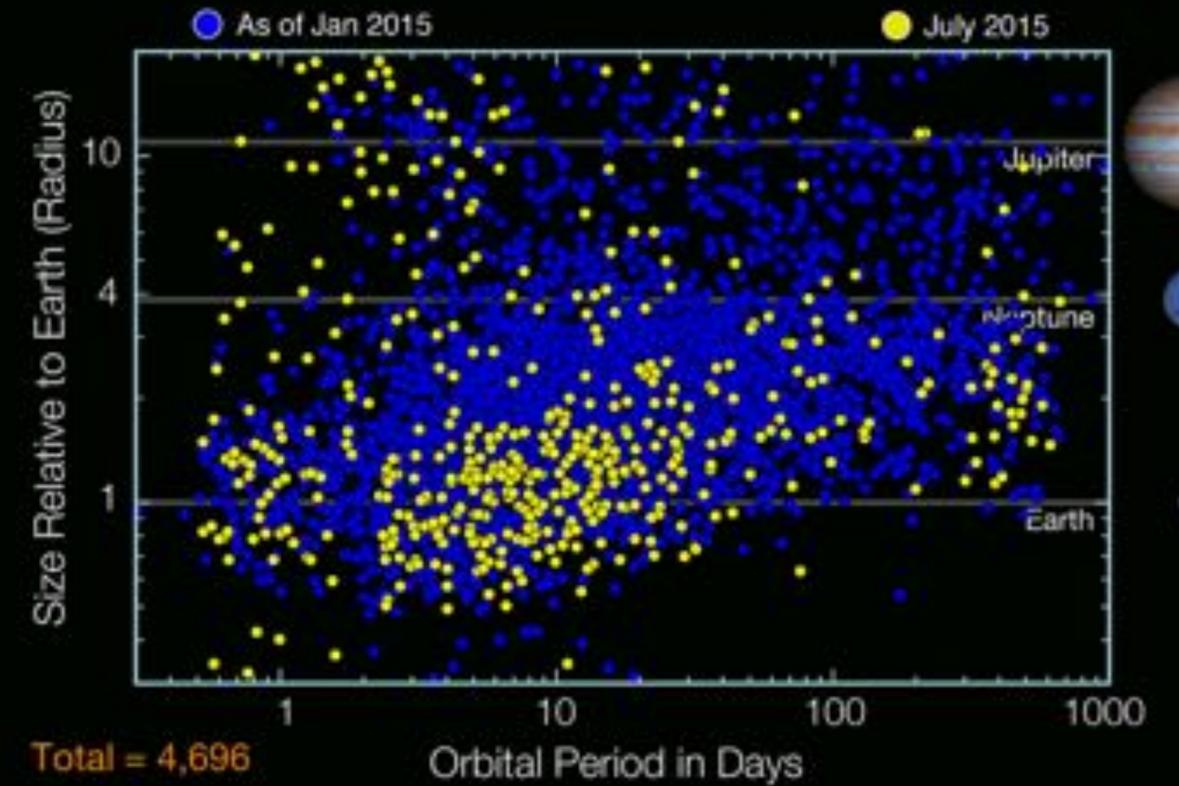
"The extreme diversity and resilience of life on earth has shown us that...wherever there's water, organic compounds, and energy, there is life."

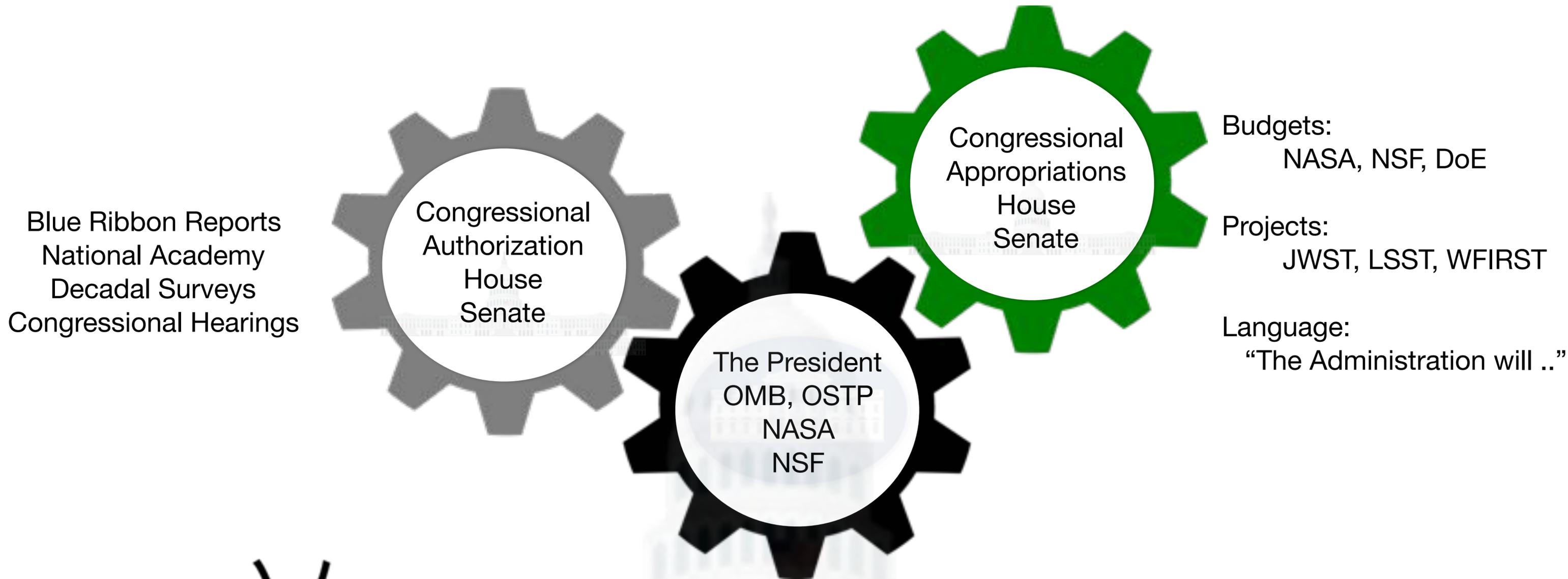
Congressional
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Commerce, Justice & Science Committee
(e.g. NASA & NSF)

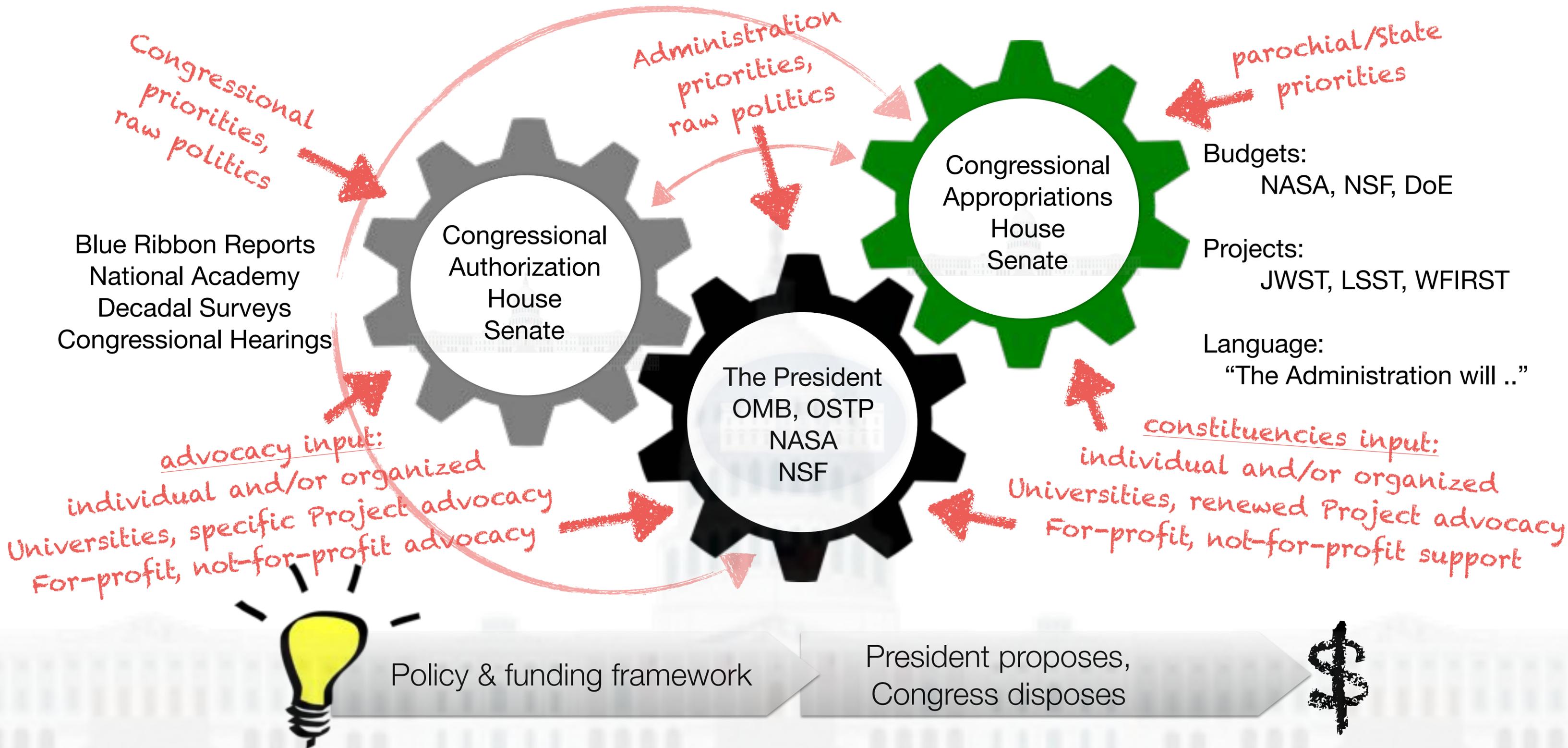
New Kepler Planet Candidates

As of July 23, 2015

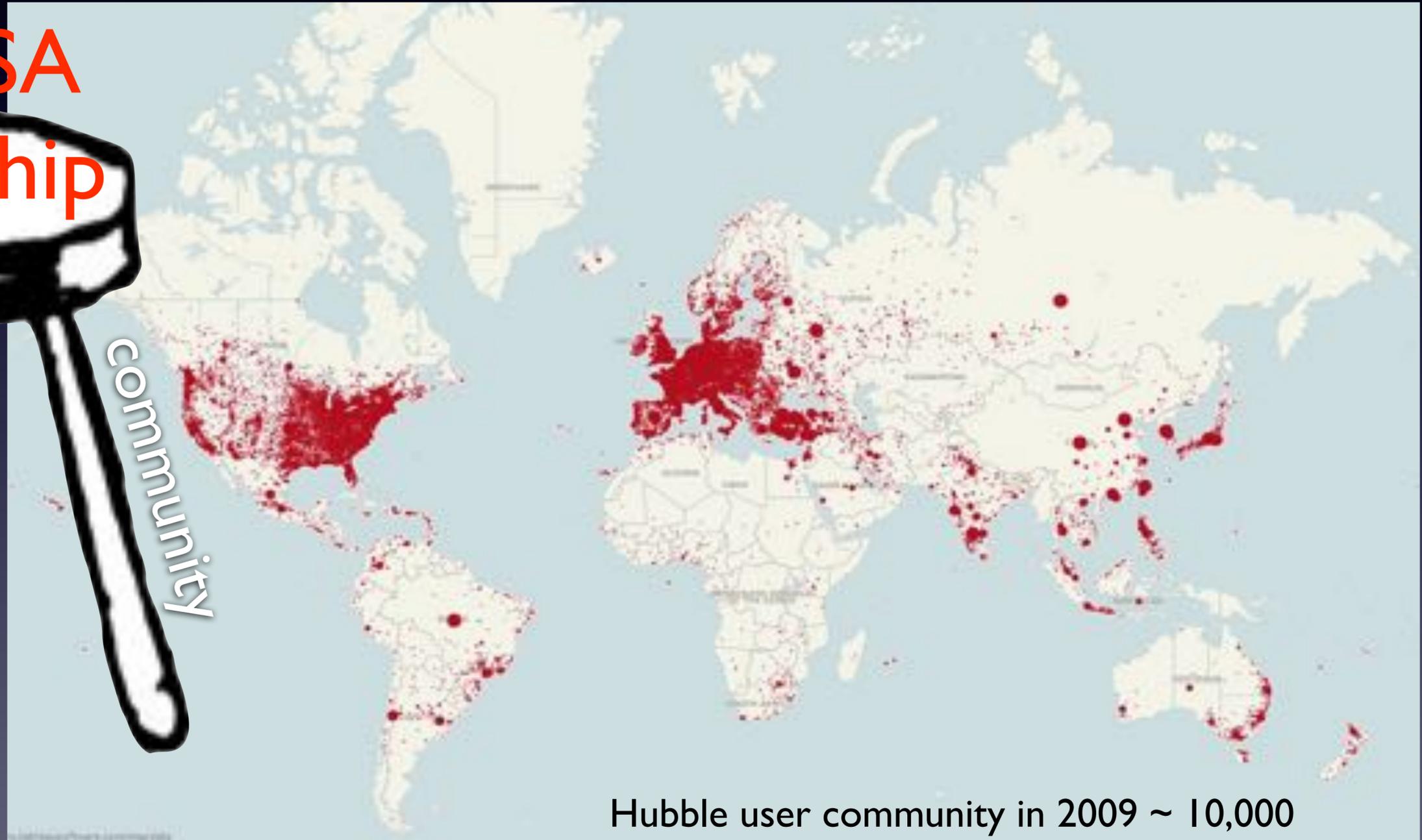
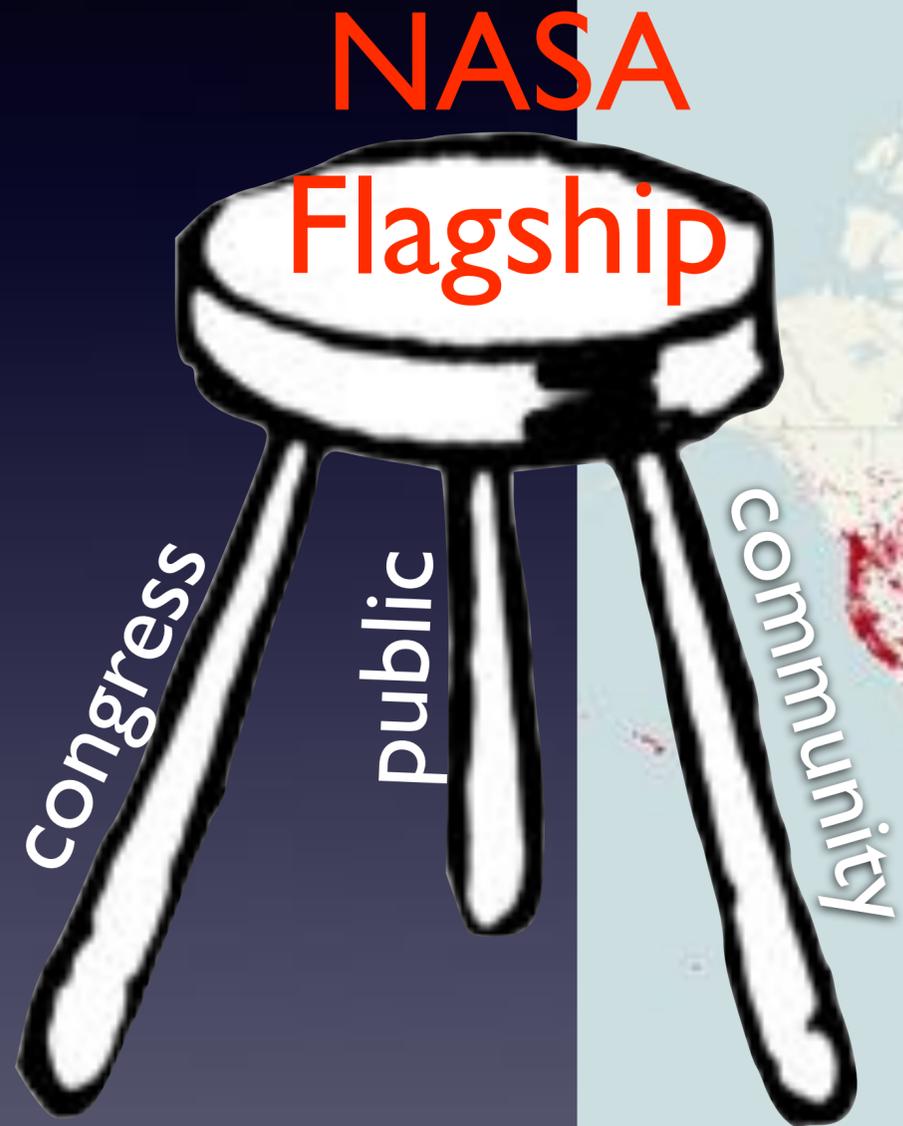




The Founding Fathers purposely created a “Rube Goldberg like” system
basic assumption: *no one constituency has a monopoly on wisdom*



Why did TPF-C, and then SIM flounder?

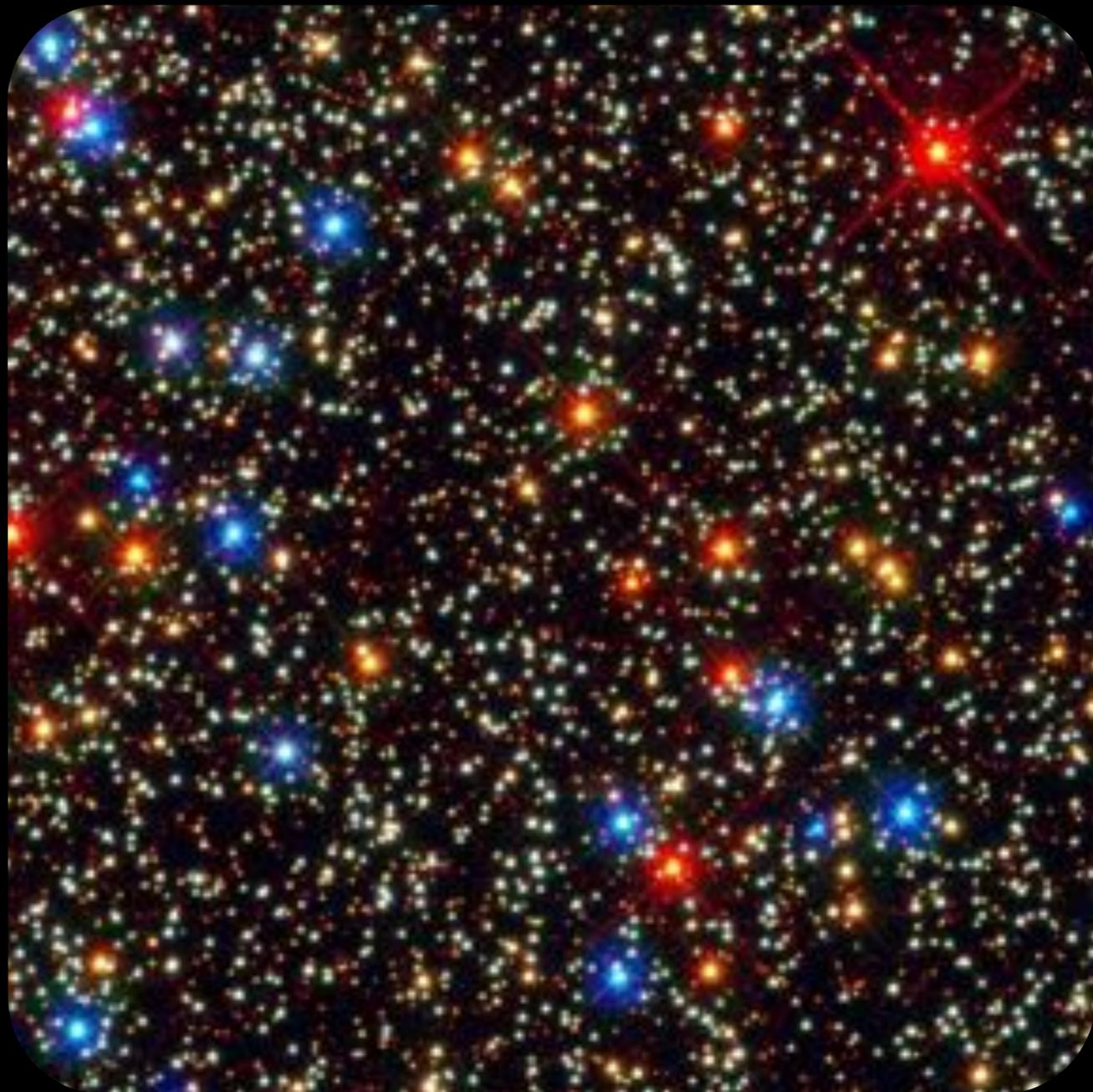


[Talk at JPL circa. 2009]

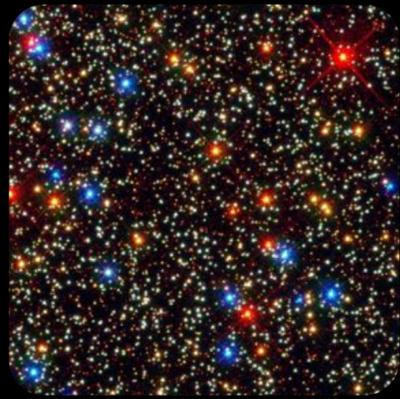
What is the breadth of the science case?



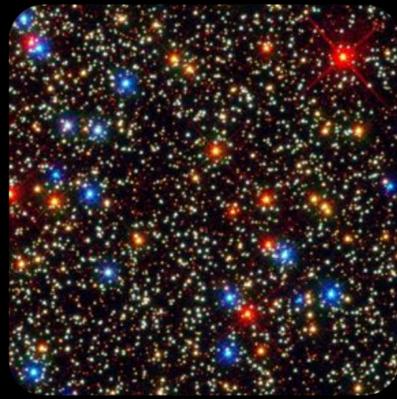
... observe structures the size of Manhattan at the orbit of Jupiter...



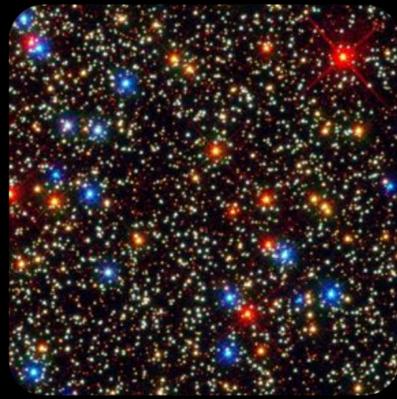
... track dark matter in
the smallest, densest
galaxies, by watching the
motion of stars...



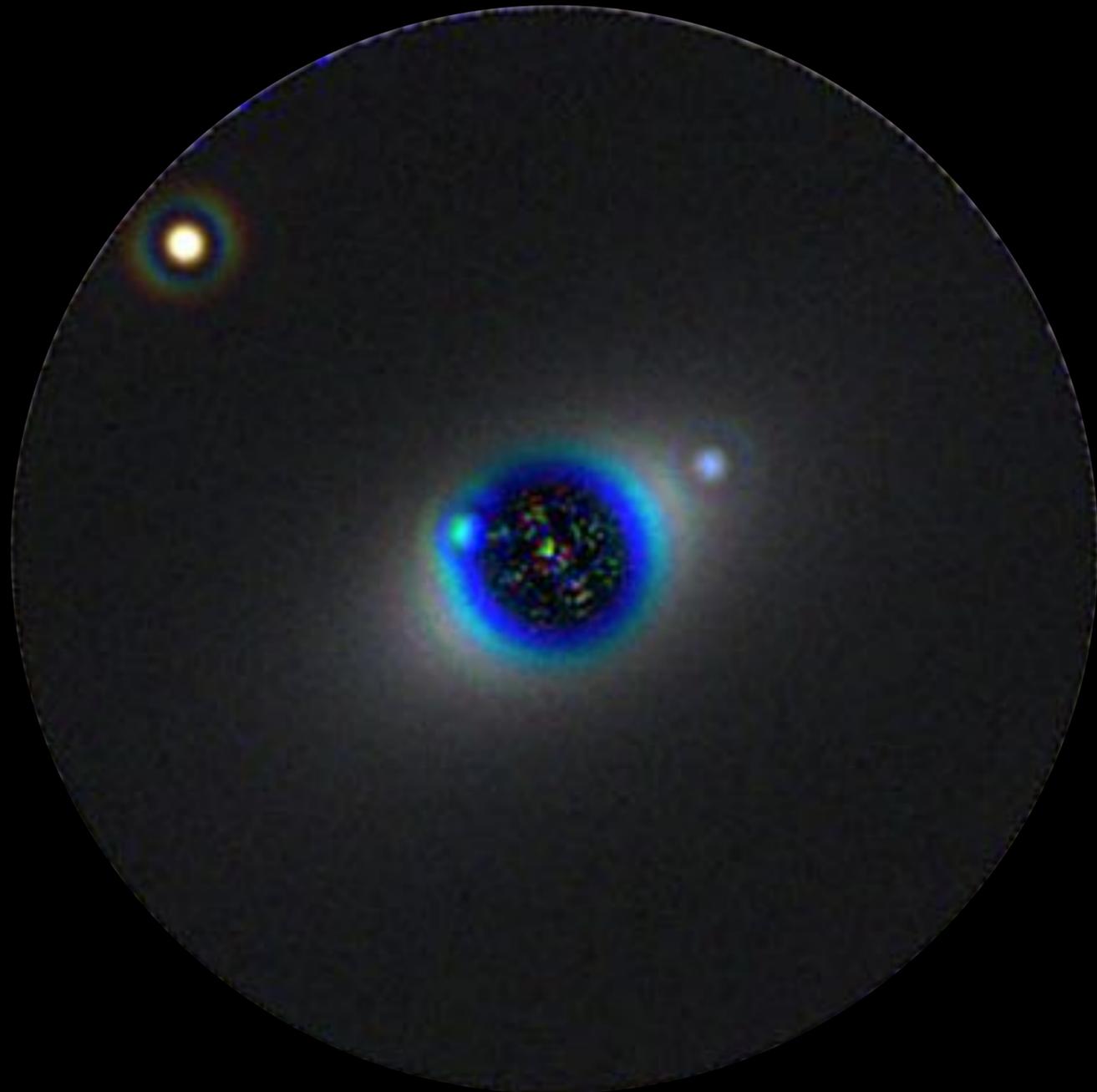
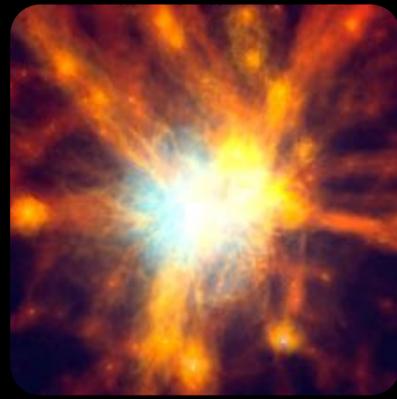
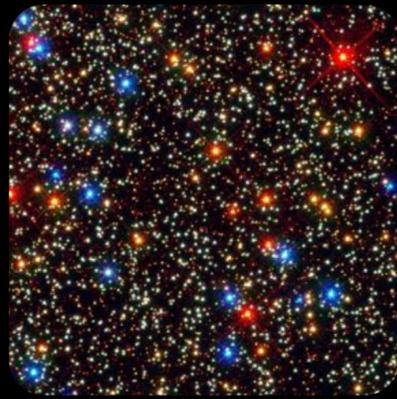
... map the nearly
invisible diffuse gas that
feeds the growth of
galaxies...



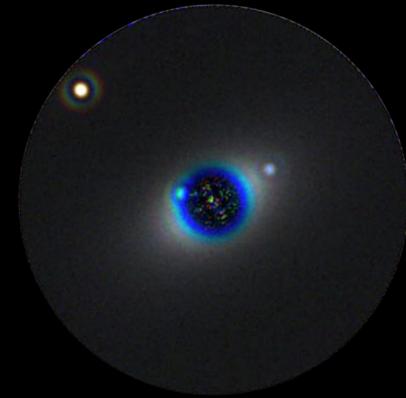
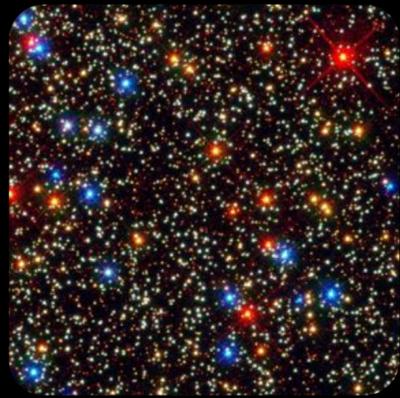
... detect every star-forming galaxy during the epoch when the Milky Way was forming...



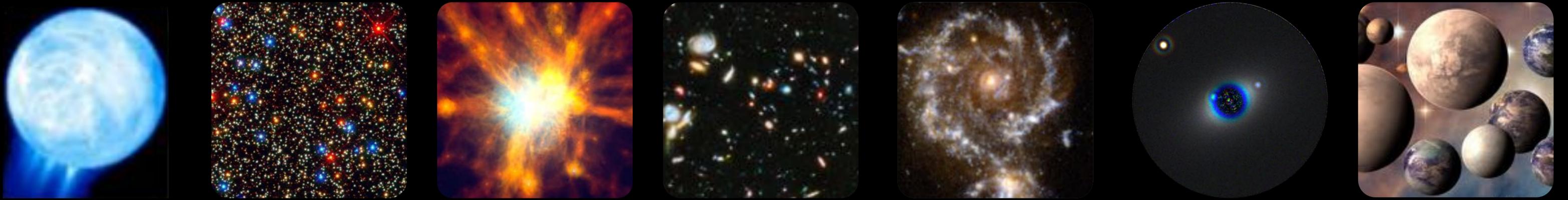
... resolve every galaxy in
the Universe into its
smallest building
blocks ...



... unravel planet
formation with hundreds
of characterized
systems...

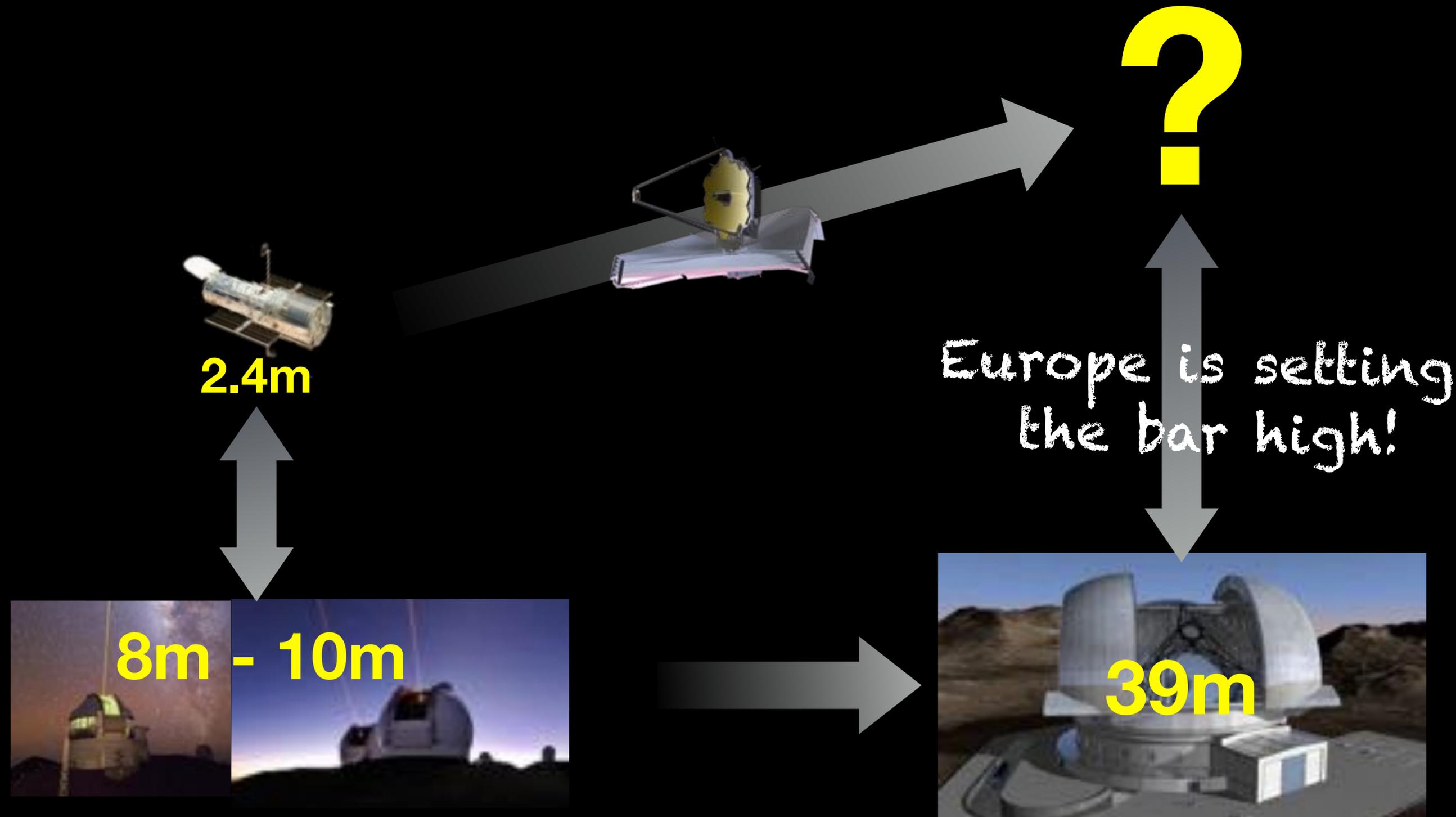


... detect dozens of
Earth-like planets to
search for evidence of
life.



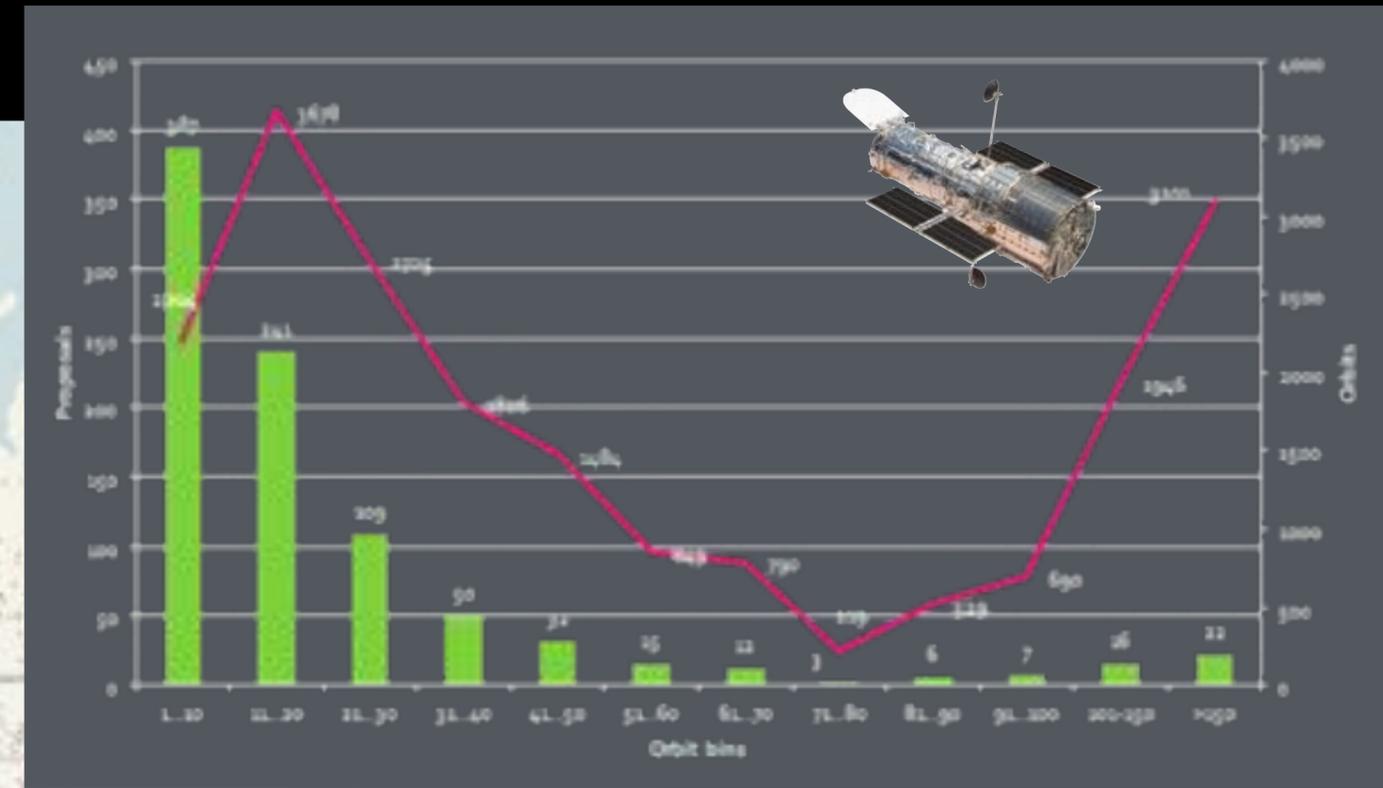
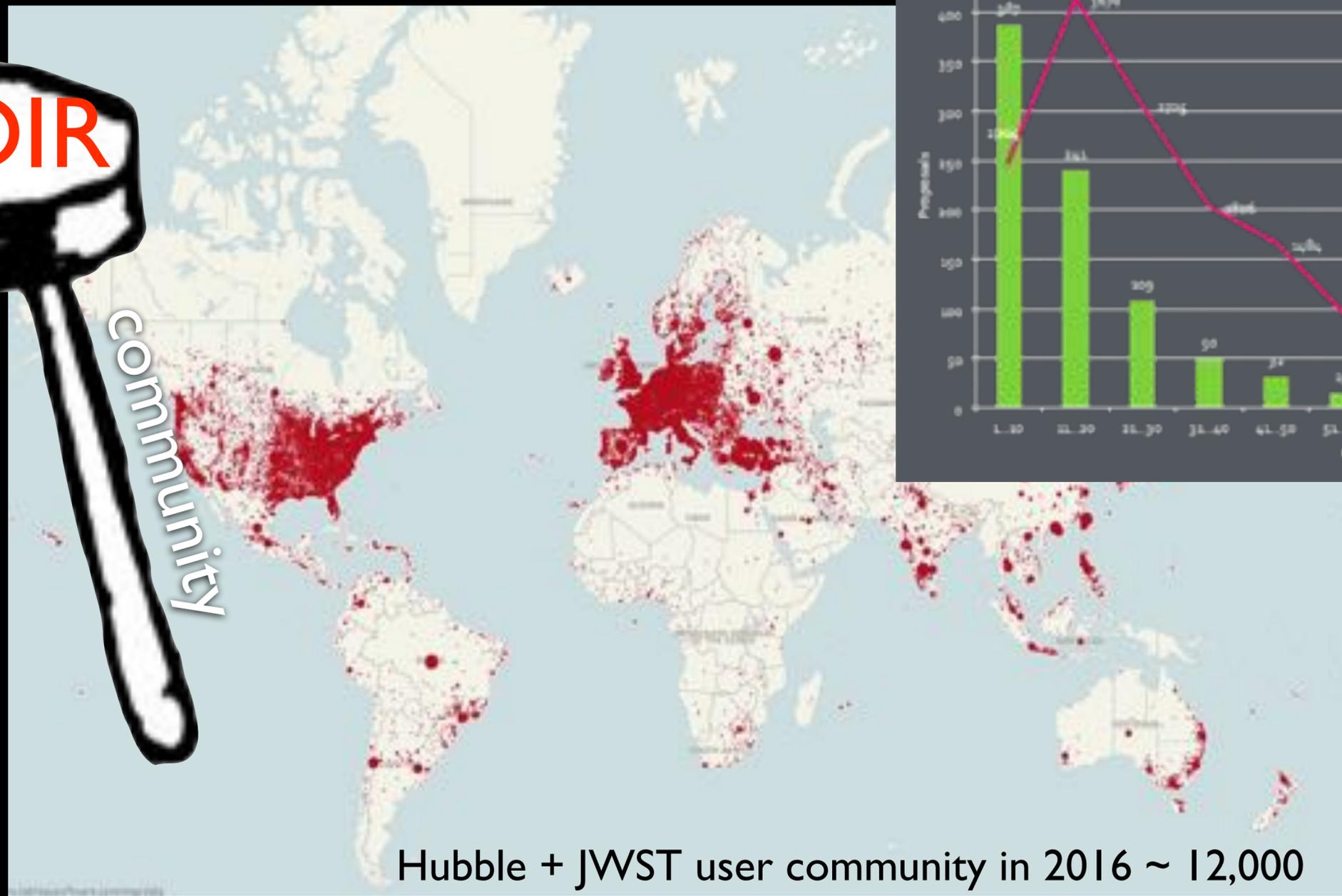
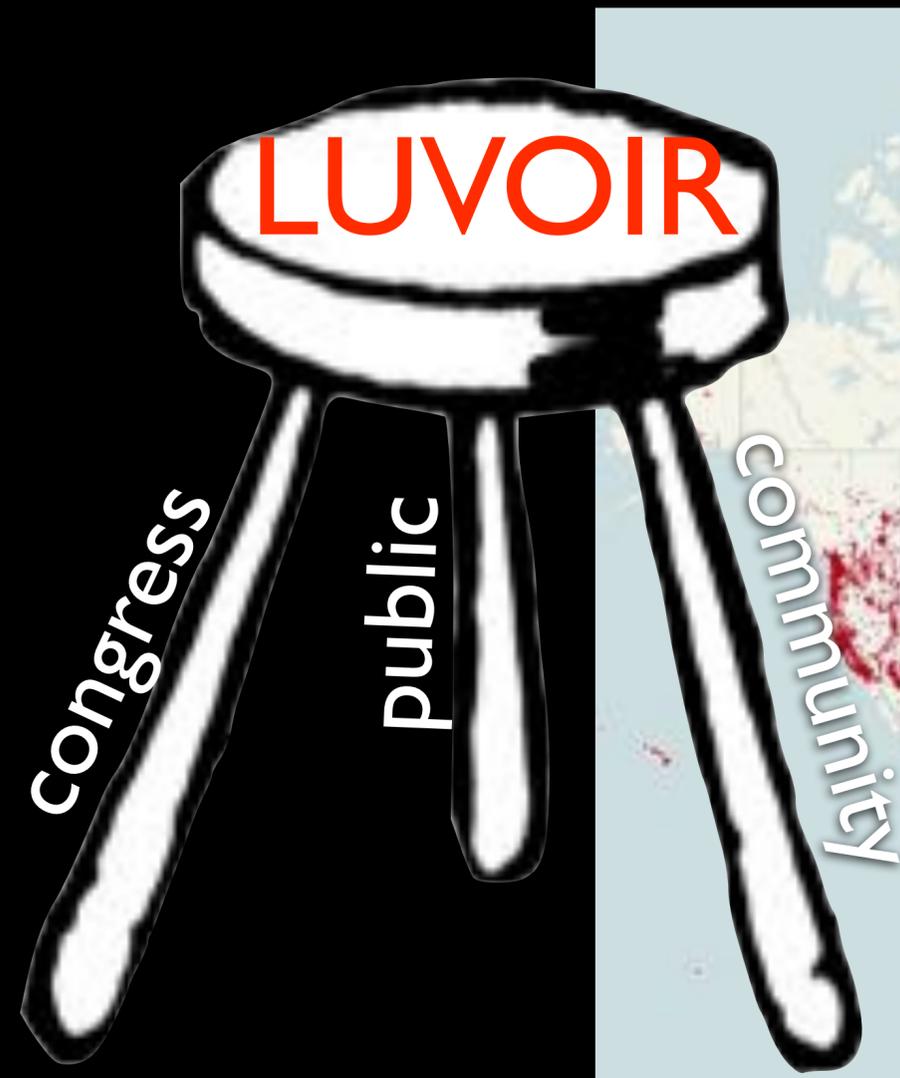
Drive revolutions across
astrophysics?

Ground based - Space based differentiation & synergy



1. Congress almost killed HST because California was building the 10m W.M Keck Telescopes
2. It has been easy to demonstrate the IR JWST can not be "out-classed" by ground based telescopes

The next transformational mission for Astrophysics will, **once again** require all three legs for support



Great Observatories support a diverse range of science, at all scales, allocating hundreds of small programs each year to individual University PI's

"The most important experiment in modern biology is the search for extra-terrestrial life."

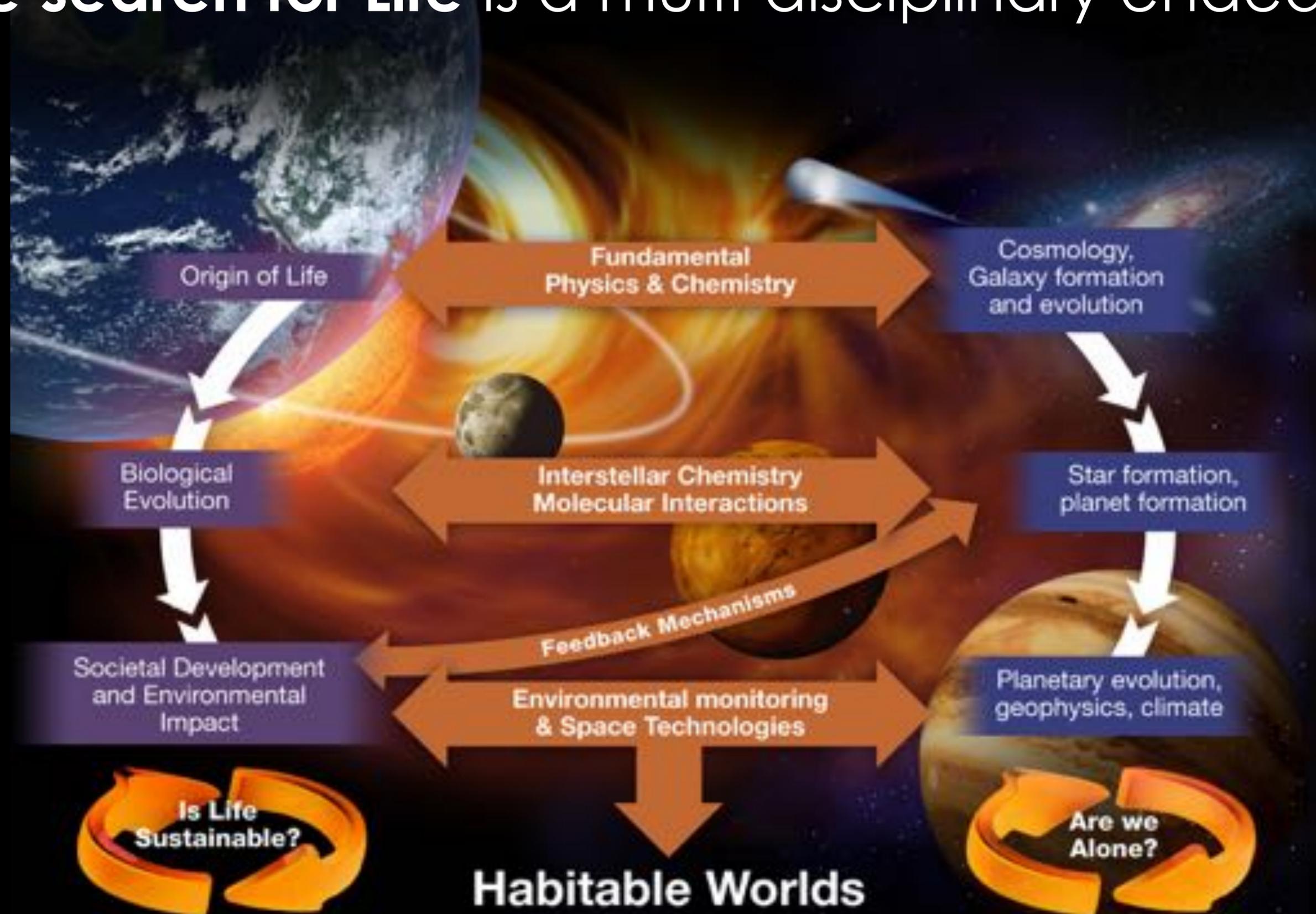
*- E. O. Wilson
Evolutionary Biologist
June 2012*



21st Century astronomers should be uniquely positioned to study "the evolution of the universe in order to relate causally the physical conditions during the Big Bang to the development of RNA and DNA" Riccardo Giacconi



The search for Life is a multi-disciplinary endeavor



To usurp a phrase from Alan Dressler, *only once in the history of sentient species is this corner turned*, the discovery they are no longer alone in the Universe.

As you all well know, with what we understand today about Exo-planets and the technologies we now have at our disposal, LUVOIR could enable this generation to uniquely take this turn, ushering in an irreversible revolution as profound as those brought about by Copernicus and Darwin.

At a more pragmatic level, in the era of ALMA, JWST, LSST and at least one ~40m ELT, we already know where the observational limits of Astrophysics will lie by the late 2020's, and an incredible landscape of science that will be untouched unless we launch something of the capabilities of LUVOIR.

And you must succeed, or there will be a generation of Astrophysicist's without their equivalent of HST, or JWST: **our future Astrophysicists need your shoulders to stand on. Who else can provide this future?**